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ELECTRIC FIELDS IN SPACE AND ON LUNAR SURFACE

By

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Introduction

Electric fields in space are important in many ways. Together with a magnetic field, a "crossed" electric field causes drift of plasma. For such a situation, the "freezing" of plasma to magnetic lines of force is not applicable. If a sufficiently strong electric field exists in regions of space, propulsion of vehicles without fuel expenditure is possible - the approach is as valid as the use of sunlight-reflecting vanes to obtain propulsion. From a basic point of view, the presence of electric fields could have implications regarding charge distributions and time rates of change of magnetic fields.

Speculations regarding electric fields are useful for outlining the nature of the problems; what is needed is a reliable measurement of the presence or absence of the electric field so that further theoretical analysis can proceed on a firm basis. At present, most theoreticians simply state that the electric fields in space are essentially zero. But this has not been verified experimentally.

It seems logical, therefore, that an effort be made to design and build a sensitive electric field measuring system whose data are unambiguously interpretable. This paper will describe such a system.

In addition to electric fields in space, those on the surface of the moon are also of great interest. These are expected to be in the range of at least a volt per centimeter, possibly more. Because such lunar-surface

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electric fields are expected to be caused by solar wind effects (including polarization charges on the highly-resistive dust layer on the surface), their measurements would have many theoretical implications.

The potential of space vehicles is a matter of concern with regard to astronaut safety, if large values occur due to unexpected causes. Also, the potential of unmanned space probes is expected to be at least a few volts, caused by both solar wind impingement and by ultraviolet solar radiation. At present the actual value, whether positive or negative, is not known. Of course in measuring the electron velocity distribution in the solar wind, one must know the vehicle potential in order to interpret the measurements correctly.

For vehicles in the magnetosphere (Van Allen belts, for example), and in the ionosphere, the question of vehicle potential and ambient electric fields is even more complicated, but none the less important.

It should not be assumed that the electric field measuring system to be described will yield answers to all of these questions and problems. However, it is believed that it will afford a start toward providing useful experimental information.

Choice of System

A review of the state-of-the-art shows that many different kinds of electric field measuring instruments have been developed. Low-frequency devices can be categorized as follows:

1. Instruments which measure the trajectories of charged particles.
2. Field mill or induction devices.
3. Potential-equalizing probes.

High-frequency devices are typically antennas, with suitable electronic frequency selection and signal amplification.

Because an excellent book by Chalmers¹ is available, no discussion of items 2 or 3 of the preceding will be given here. Such devices are not suitable for flight applications due to size, weight, power, information transmission, etc., considerations. High-frequency devices are well developed and are already being applied to space vehicles.

The use of charged particles for electric field measurement is particularly appropriate in space applications because nature has provided a vacuum environment better than any on earth. The factors of size, weight, power, etc., are also favorable. Thus, the choice for an instrument appears to be either electrons or ions. It turns out that the deflection sensitivity to ambient electric fields is the same for either particle, providing that each has the same kinetic energy. For a given ambient magnetic field, an electron beam is deflected about 500 times more than a cesium ion beam. Also, if the environment in which the system is to operate contains an appreciable flux of thermal electrons, the electron-beam system may encounter much more "noise" than the ion-beam system; that is, the fact that the ion beam represents a positive charge flow can be used in order to discriminate against background electron flow.

These considerations led to the decision to investigate the performance of a cesium ion beam for the measurement of electric fields. The questions of size, weight, power, reliability, and other important practical questions, as well as inherent sensitivity, can be answered only by construction of a laboratory system.

In addition, it was determined that the use of an electron beam for measuring electric field strength was already being investigated by Edward L. Shriver².

Description of System

→ An analytical study conducted by Northrop Space Laboratories (Dr. Samuel H. Levine) under NASA-Ames contract NAS2-2895-2 showed that a cesium ion beam instrument could measure electric fields of about 10^{-2} volts/meter. Of course such electric fields include contributions from ambient sources as well as those from spacecraft potentials. The use of two or more instruments on the opposite sides of the vehicle (or alternatively, the use of rotating vehicles) permits in principle the subtraction of the electric field of the vehicle, thus yielding the value of the ambient electric field. Well known difficulties associated with the subtraction of two large, nearly equal quantities place limitations on the usefulness of such an approach. However, accessory instrumentation that causes the spacecraft potential to pass through zero (such as emission of positive or negative charge) permits identification of the ambient electric field.

A laboratory study by Northrop Space Laboratories (Dr. Samuel H. Levine) under contract NAS2-4143 is currently in progress. Deflection sensitivity close to the theoretical value has already been achieved.

The enclosed document, "Flight Model Cesium Ion Source for Electric Field Measuring Instrument," ARD 67-1291, May 1967, describes a more refined version of the instrumentation. It is also being investigated under contract NAS2-4143.

Extrapolation from laboratory experience to date yields a total power requirement of a few watts for the flight model cesium ion beam instrumentation. The source assembly consists of a cesium reservoir with heater for temperature control, an ionizing surface with heater, accelerating electrodes, and a focusing lens. Alternative methods of detection system electronics will be explored to determine operating feasibility.

The beam requires very little cesium for operation; approximately 5 micrograms is sufficient for a year of continual operation. However, cesium is a very reactive metal and must be protected from exposure to the atmosphere from the time that the reservoir is loaded until a safe altitude (yielding a pressure of 10^{-6} torr) is attained. The projected design makes use of a blow-off plate to seal the source assembly, together with a sealed in argon blanket gas.

References

1. Atmospheric Electricity, J. Alan Chalmers, Pergamon Press, 1957.
2. NASA TM X-53435, April 12, 1966, Investigation of the Deflection of an Electron Beam as a Means of Measuring Electric Field Strength.